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Epigaeic ant (Hymenoptera: Formicidae) communities in urban parks located in Atlantic Forest biome

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Abstract: Urban parks offer refuge for numerous animal species, and some of these parks represent the remaining fragments of native forests. We evaluate the diversity and composition of epigaeic ant species (Hymenoptera: Formicidae) in urban parks located within the Atlantic Forest biome (Centenial Park, Leon Feffer Park and Villa Lobos Park). For our collections, we placed pitfall traps along 100-m line transects in areas both accessible and inaccessible to the public. A total of 46 species distributed in seven subfamilies were collected. The number of species did not differ among park areas, but the ant communities themselves differed. Native species, such as *Strumigenys denticulata* and *S. louisianae*, were collected in the most preserved natural areas in the parks. Generalist species composed the richest guild and were primarily found in areas with public access. W*asmannia auropunctata*, *Brachymyrmex heeri*, *Solenopsis* sp. 2, and *Solenopsis* sp. 3 were classified with high value as biological indicators.

Key words: urban ants; pitfall trap; visitation; biological indicator; exotic species

INTRODUCTION

The growth of urban areas leads to the loss of biodiversity (Faeth et al. 2011) because it causes significant changes in the composition, abundance, and richness of native species (Shochat et al. 2010). In addition, urban habitats often favor opportunistic species that take advantage of anthropogenic conditions (Shochat et al. 2010) to expand their area of dispersion (McIntyre et al. 2001).

The creation and maintenance of forest reserves, urban parks (Kowarik 2011), and public places (Koh and Sodhi 2004) may be a useful strategy for the conservation of biodiversity in the face of increasing urbanization. These places offer nesting resources, food, and shelter for many animal species (Koh and Sodhi 2004) and therefore, constitute biodiversity repositories (Faeth et al. 2011).

Urban planning aimed at conserving flora and fauna and improving the quality of life primarily requires the assessment of the local biodiversity (Murphy 1988; Pearson 1994). Arthropods are essential in studies of conservation strategies. They provide information on the diversity of a given area, generally have short reproductive cycles, respond quickly to environmental disturbances, are easily sampled, have several trophic levels, and are of great public health and economic importance (McIntyre 2000). Moreover, they are one of the few groups of animals that increase species richness in urban areas (Faeth et al. 2011).

In this context, ants (Hymenoptera: Formicidae) are widely used in studies on biodiversity and on the influence of urbanization on insect communities because of their biological characteristics (Lopez-Moreno et al. 2003). They are highly diverse, have numerical and biomass dominance in almost all terrestrial habitats, are easily sampled and identified in terms of species/morphospecies, and typically have stationary nests that allow resampling over time (Alonso and Agosti 2000). Ants play a key role in distinct ecosystems (Mckey et al. 2010), including nutrient cycling (Folgarait 1998) and interactions with other organisms (Hölldobler and Wilson 1990). They are also used as biological indicators of urban environments (Yamaguchi 2004, 2005). However, research has been focused on ants as vectors of pathogens in many urban areas in Brazil (Costa et al. 2006; Maia et al. 2009; Santos et al. 2009).

This study evaluated the composition, fauna similarity, and guilds in different areas of urban parks located in the city of São Paulo, where the urbanization process is intense. In addition, we present the overall list of species, including those regarded as biological indicators.

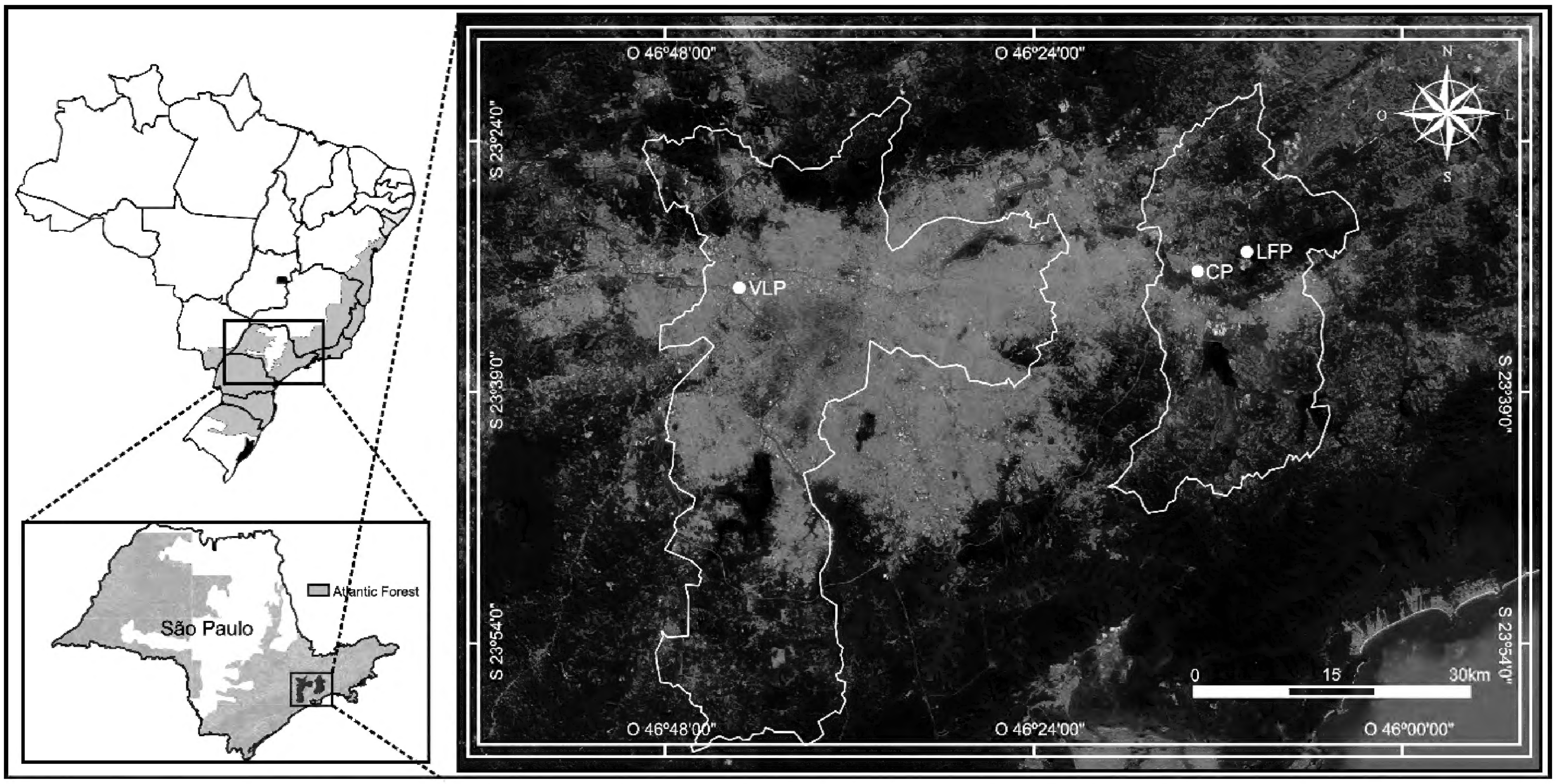

Figure 1. Location of urban parks in the state of São Paulo. CP (Centennial Park), LFP (Leon Feffer Park) and VLP (Villa Lobos Park).

MATERIALS AND METHODS

Study site

Samples were collected at urban parks in cities located in the Atlantic Forest biome, in southeastern Brazil (Fiaschi and Pirani 2009; Colombo and Joly 2010). In the city of Mogi das Cruzes, data collections were made in the Centennial Park (21.5 ha) and Leon Feffer Park (26 ha); in the city of São Paulo, they were made in the Villa Lobos Park (73.2 ha) (Figure 1). All three parks have native vegetation woods that are not open to the public.

Mogi das Cruzes and São Paulo have a population of 429,321 and 12,038,175 (IBGE 2016), respectively. The prevailing climate is high-altitude humid tropical (Cwa, Köppen climate classification [1948]) with rainy summers and dry winters. The annual average temperature is 21°C, relative humidity is 80%, and rainfall is 1.700 mm.

Data collection

Between December 2012 and February 2013, every two months, a data collection expedition was made in each urban park. Surveys were carried out during the weekends, due to the high number of visitors. We used pitfall traps, since only a thin layer of litter covers the soil in the parks (see discussion in Lopes and Vasconcelos 2008). Ten pitfall traps were distributed along six linear 100-m transects within each park, divided in three transects in public access areas and three in closed to the public areas. Therefore, six sampling expeditions were made to each urban park, totalling 180 traps, 90 in public access areas 90 in area not open to the public. Linear transects covered different microhabitats in each park; however, they had similar characteristics between both types of areas. The traps remained in the field for 24 hours in order to avoid their removal by visitors.

Taxonomy follows Bolton (2013). Ants were identified using Brady et al. (2014) and Baccaro et al. (2015). Taxa unidentified to species are listed by generic name followed by "sp." in the same manner used by Suguituru et al. (2015) in a similar, but larger study. Voucher specimens were deposited in the ant fauna regional reference collection of Alto Tiete (University of Mogi das Cruzes), curated by Dr. Maria Santina de Castro Morini. Collections were approved by the Ministry of the Environment/Biodiversity Authorization and Information System (Ministério do Meio Ambiente/Sistema de Autorização e Informação em Biodiversidade - MMA/SISBIO) under license no. 34037-1.

Data analysis

The number total of species (richness) in public access areas and in area not open to the public was compared using accumulation curves (EstimateS software version 9.0; Colwell 2013) and the Mann–Whitney U test (BioEstat software version 5.0; Ayres et al. 2007). Relative frequency was calculated based on the number of occurrences of each species (presence and absence data) (Gotelli and Colwell 2001). Ant communities were described using Shannon–Wiener diversity index (H′), Equitability and Jaccard index (J). A significance level of 5% was used.

The biological indicators were characterized using the Dufrêne and Legendre (1997) Method. The analysis was made using PCORD 6.2 software (McCune and Mefford 2011), were tested using Monte Carlo randomization tests (randomization = 999, p<0,05). The index varies

from 0 to 100%, with zero indicating that there is no association between the species and the environment. Species with values ranging from 50 to 70% are considered to be detectors; species with values higher than 70% are indicators; and species with 100% are exclusive to a certain habitat (Verdú et al. 2011; Leivas and Carneiro 2012). All species found were grouped into guilds on the basis of trophic preferences and foraging location, following the proposed Silvestre et al. (2003) and Brandão et al. (2009).

RESULTS

A total of 5,334 specimens were collected, and the total richness was 46 species/morphospecies. Myrmicinae (56.5%) was the richest subfamily in all parks, followed by Formicinae (17.3%). Dorylinae and Ectatomminae had a single species each (2.1%) (Table 1). The richest genus was *Pheidole*, with *Pheidole obscurithorax* (Naves, 1985), *Pheidole* sp. 21, and *Solenopsis saevissima* (Mayr, 1862) being the most frequent species. Thirteen species occurred only in public access areas; whereas 11 species, such as *Strumigenys denticulata* (Mayr, 1887), *S. louisianae* (Roger, 1863) and *Odontomachus chelifer* (Latreille, 1809), were exclusively collected in areas not open to the public (Table 1).

We collected 33 species in public access areas and 34 in areas not open to the public (Figure 2). The richness did not differ (U = 0.948, $p > 0.05$), the similarity between the areas was low (J = 0.386), and areas open to the public were the most diverse ones (H′ = 1.44) (Table 1). *Dorymyrmex brunneus* (Forel, 1908), *Linepithema neotropicum* (Wild, 2007), and *Nylanderia* sp. 1 were more frequently reported in areas with public access. *Pachycondyla striata* (Smith, 1858) and some *Pheidole* species were more frequent in areas without public access (Table 1).

Twenty-seven species (58.69%) were recorded in both areas (Table 1). *Solenopsis* sp. 2, *Solenopsis* sp. 3, and *Wasmannia auropunctata* (Roger, 1863) were indicator species of areas with and without public access (Table 1). *Brachymyrmex heeri* (Forel, 1874) (Indval = 100%) was an indicator species for areas with public access. *Acromyrmex niger* (F. Smith, 1858), *Myrmelachista catharinae* (Mayr, 1887), *Odontomachus affinis* (Guérin-Menévilli, 1844), *Oxyepoecus myops* (Albuquerque & Brandão,

Table 1. Absolute frequency (in parentheses), relative frequency (%), and biological indicator value of ant species according to urban park areas. Species identification see appendix.

Taxonomic list	Park area: Visited	Park area: Unvisited	Indicator value (%)
Dolichoderinae			
Dorymyrmex brunneus (Forel, 1908)	(9) 5.52	(5) 4.03	–
Linepithema neotropicum Wild, 2007	(8) 4.91	–	50
Formicinae			
Camponotus crassus (Mayr, 1862)	(2) 1.23	(6) 4.84	–
Camponotus rufipes (Mayr, 1862)	(9) 5.52	(6) 4.84	–
Camponotus sp. 5	(4) 2.45	–	–
Camponotus sp. 11	(6) 3.68	–	50
Brachymyrmex admotus (Mayr, 1887)	(8) 4.91	(3) 2.42	–
Brachymyrmex cordemoyi (Forel, 1895)	–	(3) 2.42	–
Brachymyrmex heeri (Forel, 1874)	(1) 0.61	–	100
Myrmelachista catharinae (Mayr, 1887)	–	(1) 0.81	50
Nylanderia sp. 1	(8) 4.91	(3) 2.42	–
Dorylinae			
Labidus coecus ((Latreille, 1802)	(5) 3.07	(2) 1.61	–
Ectatomminae			
Gnamptogenys striatula (Mayr, 1884)	(9) 5.52	(5) 4.03	–
Myrmicinae			
Acromyrmex niger (F. Smith, 1858)	–	(2) 1.61	50
Atta sexdens (Linnaeus, 1758)	–	(2) 1.61	26.4
Cardiocondyla wroughtonii (Forel, 1890)	(1) 0.61	–	50
Cephalotes pusillus (Klug, 1824)	(1) 0.61	–	50
Cyphomyrmex (gr. *rimosus*)	(1) 0.61	–	50
Oxyepoecus myops (Albuquerque & Brandão, 2009)	–	(1) 0.81	50
Pheidole aberrans (Mayr, 1868)	(4) 2.45	(1) 0.81	25.2
Pheidole obscurithorax (Naves, 1985)	(10) 6.13	(9) 7.26	–
Pheidole oxyops (Forel, 1908)	(4) 2.45	(2) 1.61	–
Pheidole sospes (Forel, 1908)	(4) 2.45	(3) 2.42	–
Pheidole triconstricta (Forel, 1886)	(5) 3.07	–	
Pheidole sp. 5	–	(1) 0.81	50
Pheidole sp. 21	(10) 6.13	(10) 8.06	–
Pheidole sp. 24	(3) 1.84	(4) 3.22	–
Pheidole sp. 26	(1) 0.61	–	50
Pheidole sp. 36	(8) 4.91	(10) 8.06	–
Pheidole sp. 38	–	(3) 2.42	50
Pheidole sp. 39	(1) 0.61	–	50
Pheidole sp. 44	–	(1) 0.81	50
Solenopsis saevissima (Mayr, 1862)	(10) 6.13	(10) 8.06	–
Solenopsis sp. 2	(7) 4.29	(5) 4.03	100*
Solenopsis sp. 3	(3) 1.84	(1) 0.81	100*
Strumigenys denticulata (Mayr, 1887)	–	(1) 0.81	50
Strumigenys louisianae (Roger, 1863)	–	(1) 0.81	50
Wasmannia affinis (Santschi, 1929)	(3) 1.84	(2) 1.61	–
Wasmannia auropunctata (Roger, 1863)	(4) 2.45	(5) 4.03	100*
Ponerinae			
Hypoponera sp. 1	(6) 3.68	–	50
Hypoponera sp. 11	(1) 0.61	–	–
Odontomachus affinis (Guérin-Ménevilli, 1844)	(1) 0.61	(1) 0.81	50
Odontomachus chelifer (Latreille, 1809)	–	(4) 3.22	46.8
Pachycondyla striata (Smith, 1858)	(5) 3.07	(10) 8.06	–
Pseudomyrmecinae			
Pseudomyrmex gracilis (Ward, 1999)	–	(1) 0.81	50
Pseudomyrmex sp. 3	(1) 0.61	–	50
Observed partial richness	34	33	
Observed total richness	46		
Partial abundance (area)	3.081	2.253	
Abundance total	5.334		
Diversity	1.44	1.38	
Equitability	0.93	0.91	

* Values in bold indicate association (significative value p) with the two area types.

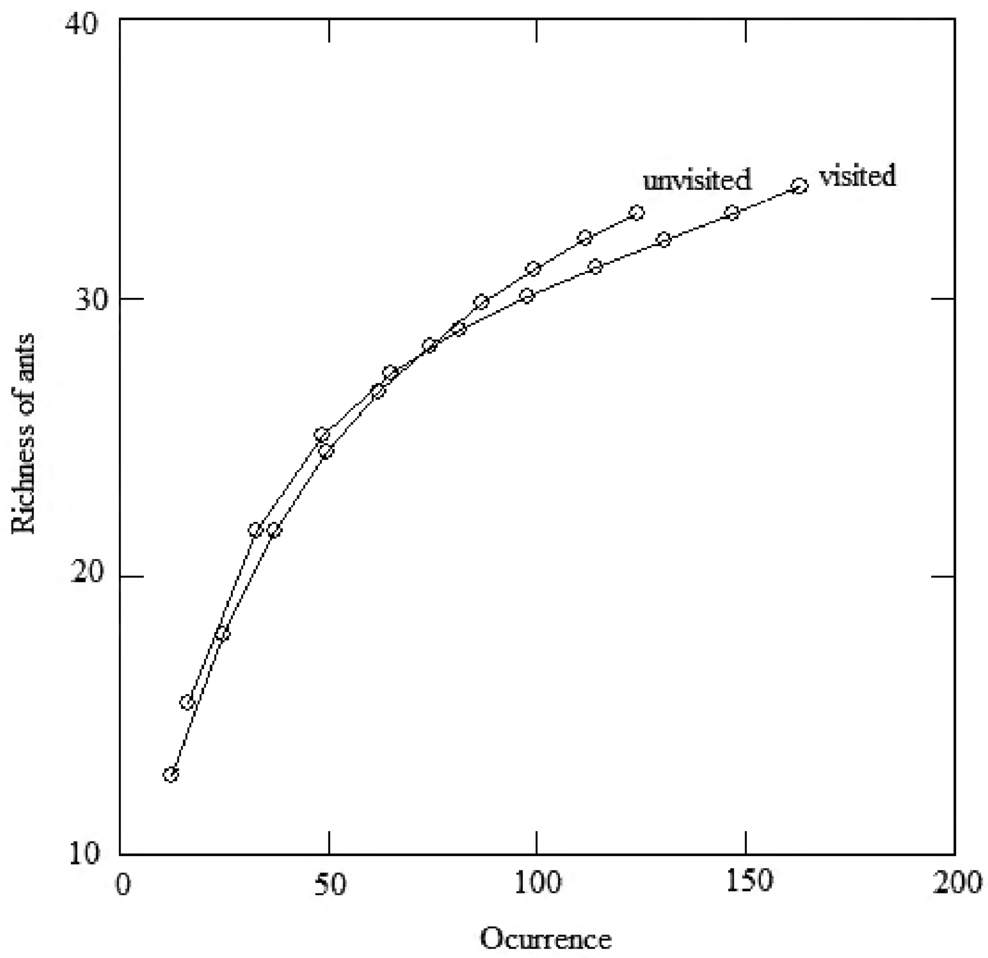

Figure 2. Comparison of the richness of ant species between urban park areas with and without public access.

2009), *Pheidole* sp. 5, *Pheidole* sp. 38, *Pheidole* sp. 44, *Pseudomyrmex gracilis* (Ward, 1999), *Strumigenys denticulata*, and *S. louisianae* (all with Indval = 50%) appeared to be indicators of areas without public access (Table 1).

A total of 13 guilds were recorded (Table 2). The soil-dominant omnivores were the richest guild and this group, included species from the genera: *Dorymyrmex, Camponotus, Pheidole*, and *Solenopsis*. The less rich guilds included the small arboreal species with massive recruitment (*M. catharinae*), opportunistic species in the soil and vegetation (*Nylanderia* sp. 1), secondary forest specialists, epigaeic army ants (*Labidus coecus* [Jurine, 1807]), forest litter predators (*Gnamptogenys striatula* [Mayr, 1884]), and Cephalotini species (Table 2). The Myrmicinae predator cryptic specialist guild was found only in areas without public access; and a single exotic species, *Cardiocondyla wroughtonii* (Forel, 1890), was found in area not open to the public.

Table 2. Richness of ant species in each guild according to urban park areas (based on pitfall sampling).

	Guilds	Visited	Unvisited
1	Dominant soil omnivorous	19	17
2	Small arboreal with massive recruitment	1	–
3	Opportunistic soil and vegetation	3	3
4	Specialist miminal vegetation	–	1
5	Legion epigaeic	1	1
6	Litter predators	1	1
7	Cutter fungus–growers	–	2
8	Cephalotini	1	–
9	Cryptic Attini fungus–growers	1	–
10	Myrmicinae predator cryptic specialist	–	2
11	Cryptic predator arboreal specialist	2	2
12	Ponerinae cryptic predator specialist	2	–
13	Large predator epigaeic	2	3
14	Pseudomyrmecinae predatory arboreal agile	1	1

DISCUSSION

Results suggest that public access in urban parks does not affect total richness of ant species that forage along the ground, but it affects species diversity. Urban parks generally have a poor phytophysiognomy due to anthropic interferences and the more open canopy. In this case, the soil is exposed to intense sunlight, which modifies the microclimate and the decomposition rates of litter and its components (Louzada et al. 1997). These factors influence food and nidification sites availability and variety that are, in part, responsible for the diversity of ants (Benson and Harada 1988; Folwer et al. 1991; Arruda et al. 2015). However, even with these negative factors that are inherent to urban parks, areas without public access provide microhabitats for Atlantic Forest litter characteristic species, according to the taxonomic list reported by Pacheco et al. (2009) and Suguituru et al. (2013, 2015).

Areas without public access support a greater number of native species, such as Ponerinae and some Myrmicinae. Thus, the proximity of natural areas and/or a native forest inside these parks can be determining factors for biodiversity maintenance in areas of urban vegetation (Pacheco and Vasconcelos 2007). Nevertheless, more generalist species might be favored by the anthropic interference in the native woods that compose urban park landscapes in the present study, and especially in public visited areas, where they were collected more frequently.

Strumigenys is a Myrmicinae genus considered to be a cryptic predator specialized in feeding on springtails and other small arthropods (Delabie et al. 2000; Brandão et al. 2003). *Strumigenys* species have been reported to occur in litter from the best-preserved areas of Atlantic Forest (Suguituru et al. 2013, 2015). On the other hand, they were also collected in other urban parks in São Paulo (Ribeiro et al. 2012) and in urban squares surrounded by native vegetation (Suguituru et al. 2015). This suggests that these species can also live in environments sinantropic (Lattke and Goitía 1997). In the present study, *S. denticulata* and *S. louisianae* were classified as biological indicators of areas without public access. Our results corroborate the findings of Pacheco and Vasconcelos (2007) who reported *Brachymyrmex* species as biological indicators of urban parks as well as commercial and residential areas with intense public access.

A low number of exotic species was recorded compared with the results of other studies (see Ribeiro et al. 2012; Melo et al. 2014), although the parks are located in highly anthropogenic environments. *Cardiocondyla wroughtonii* originated in Asia (Bueno and Campos-Farinha 1999) and has the potential to compete with and reduce the

native fauna (Pacheco and Vasconcelos 2007; Hoffmann 2010). In the present study, *C. wroughtonii* was also classified as a biological indicator. Future monitoring of this population is important because, in 2002, this species was not included in the list of important urban ants in southeast Brazil (Campos-Farinha et al. 2002).

Moreover, the monitoring of *W. auropunctata*, a species originally from the Neotropical region, is equally important, it is listed as one of the '100 of the World's Worst Invasive Alien Species' (Lowe et al. 2000). This species is strongly associated with the urban parks we studied, which supports the results of Ribeiro et al. (2012), and with other urban areas (Campos-Farinha et al. 2002). It is known as the "little fire ant" because of its painful sting, and similar to *Solenopsis invicta* Buren 1972 (red fire ant), it is a public health problem (Souza 2007; More et al. 2008). *Wasmannia auropunctata* has an aggressive behavior toward the native fauna and conquers new territories through budding (polydomy) and intranidal mating (Souza 2007). These behaviors are common in invasive species (Passera 1994).

This study adds two genera and 11 species to the taxonomic list of urban forested areas in Mogi das Cruzes (Souza et al. 2012) and approximately 28 species to the urban parks in São Paulo (Ribeiro et al. 2012). It corroborates the study of Ribeiro et al. (2012) with respect to the dominance of *Pheidole* and *Solenopsis* species, and it demonstrates that the urban parks share many ant species found in the litter layer of preserved areas of the Atlantic Forest, especially in areas not open to the public.

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APPENDIX

Photos and identification of the species collected in the parks studied. The vouchers were deposited in the ant fauna reference collection of Alto Tiete (University of Mogi das Cruzes). Photos: Suguituru et al. (2015).

Figure A1. Subfamily Dolichoderinae: *Dorymyrmex brunneus.*

Figure A2. Subfamily Dolichoderinae: *Labidus coecus*.

Figure A3. Subfamily Dolichoderinae: *Linepithema neotropicum*.

Figure A4. Subfamily Formicinae: *Brachymyrmex admotus*.

Figure A5. Subfamily Formicinae: *Brachymyrmex cordemoyi*

Figure A6. Subfamily Formicinae: *Brachymyrmex heeri*.

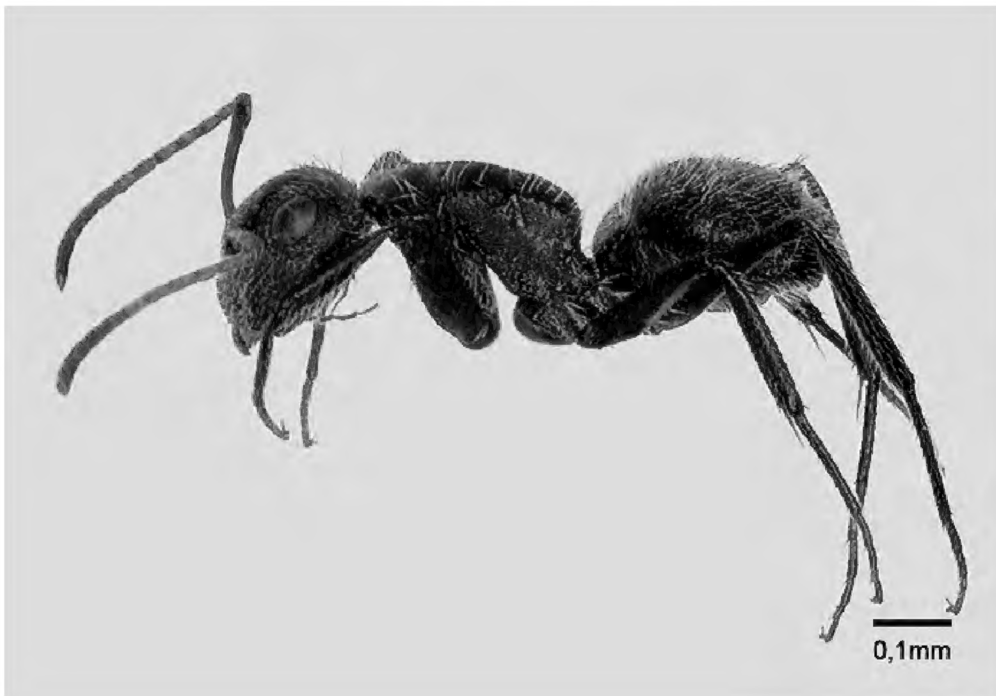

Figure A7. Subfamily Formicinae *Camponotus crassus*.

Figure A8. Subfamily Formicinae: *Camponotus rufipes.*

Figure A9. Subfamily Formicinae: *Camponotus* sp. 5.

Figure A10. Subfamily Formicinae: *Camponotus* sp. 11.

Figure A11. Subfamily Formicinae: *Myrmelachista catharinae*.

Figure A12. Subfamily Formicinae: *Nylanderia* sp. 1.

Figure A13. Subfamily Ectatominnae: *Gnamptogenys striatula*.

Figure A14. Subfamily Subfamily Myrmicinae: *Acromyrmex niger.*

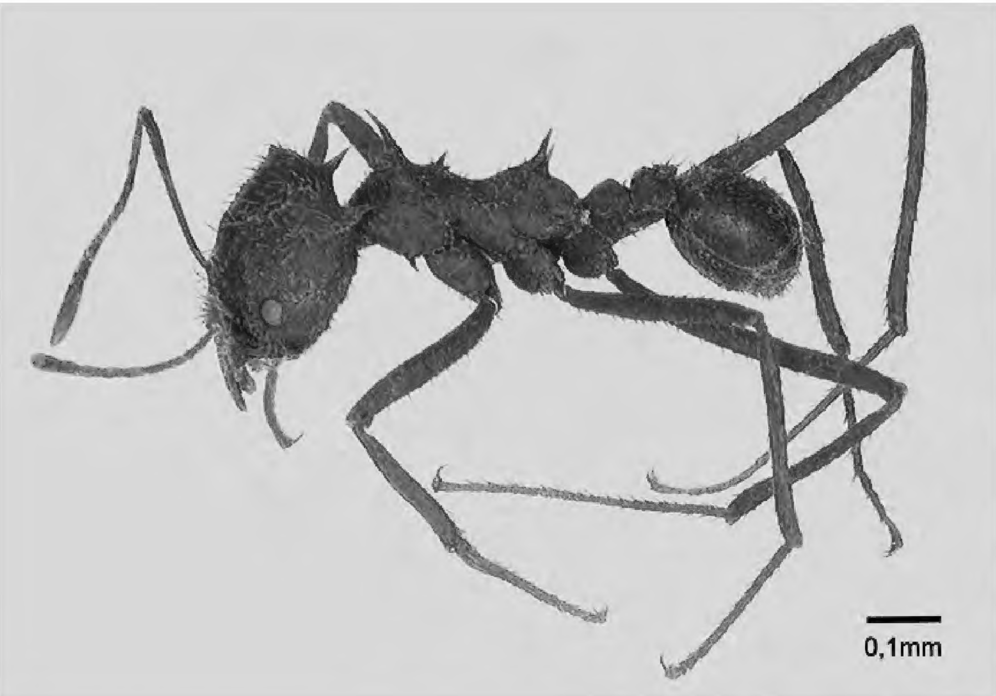

Figure A15. Subfamily Myrmicinae: *Atta sexdens.*

Figure A16. Subfamily Myrmicinae: *Cardiocondyla wroughtonii.*

Figure A17. Subfamily Myrmicinae: *Cephalotes pusillus*.

Figure A18. Subfamily Myrmicinae: *Cyphomyrmex* (gr *rimosus*).

Figure A19. Subfamily Myrmicinae: *Oxyepoecus myops.*

Figure A20. Subfamily Myrmicinae: *Pheidole aberrans.*

Figure A21. Subfamily Myrmicinae: *Pheidole obscurithorax.*

Figure A22. Subfamily Myrmicinae: *Pheidole oxyops.*

Figure A23. Subfamily Myrmicinae: *Pheidole sospes.*

Figure A24. Subfamily Myrmicinae: *Pheidole* sp. 5.

Figure A25. Subfamily Myrmicinae: *Pheidole* sp. 21.

Figure A26. Subfamily Myrmicinae: *Pheidole* sp. 24.

Figure A27. Subfamily Myrmicinae: *Pheidole* sp. 26.

Figure A28. Subfamily Myrmicinae: *Pheidole* sp. 36.

Figure A29. Subfamily Myrmicinae: *Pheidole* sp. 38.

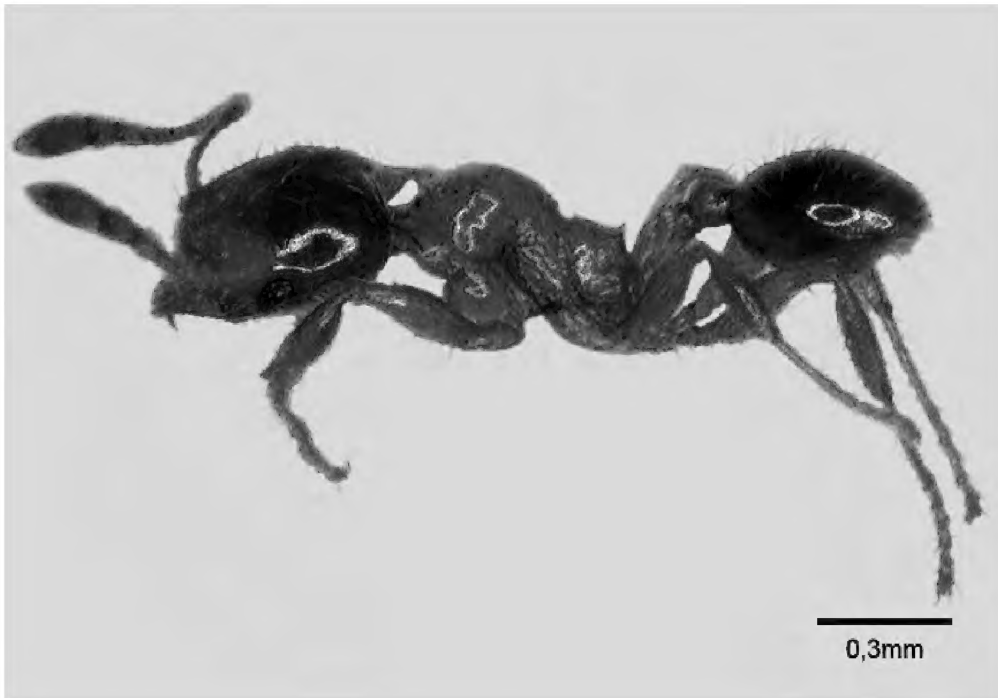

Figure A30. Subfamily Myrmicinae: *Pheidole* sp. 39.

Figure A31. Subfamily Myrmicinae: *Pheidole* sp. 44.

Figure A32. Subfamily Myrmicinae: *Pheidole* sp. 44.

Figure A33. Subfamily Myrmicinae: *Solenopsis saevissima.*

Figure A34. Subfamily Myrmicinae: *Solenopsis* sp. 2.

Figure A35. Subfamily Myrmicinae: *Solenopsis* sp. 3.

Figure A36. Subfamily Myrmicinae: *Strumygenys denticulata.*

Figure A37. Subfamily Myrmicinae: *Strumygenys louisianae.*

Figure A38. Subfamily Myrmicinae: *Wasmannia affinis*.

Figure A39. Subfamily Ponerinae: *Hypoponera* sp. 1.

Figure A40. Subfamily Ponerinae: *Hypoponera* sp. 11.

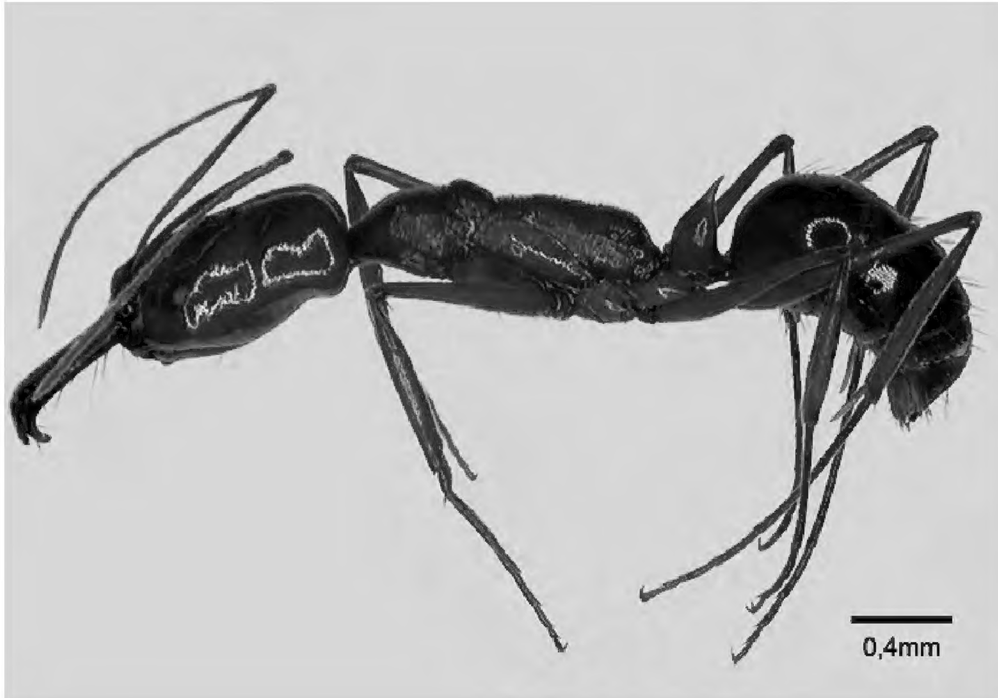

Figure A41. Subfamily Ponerinae: *Odontomachus affinis*.

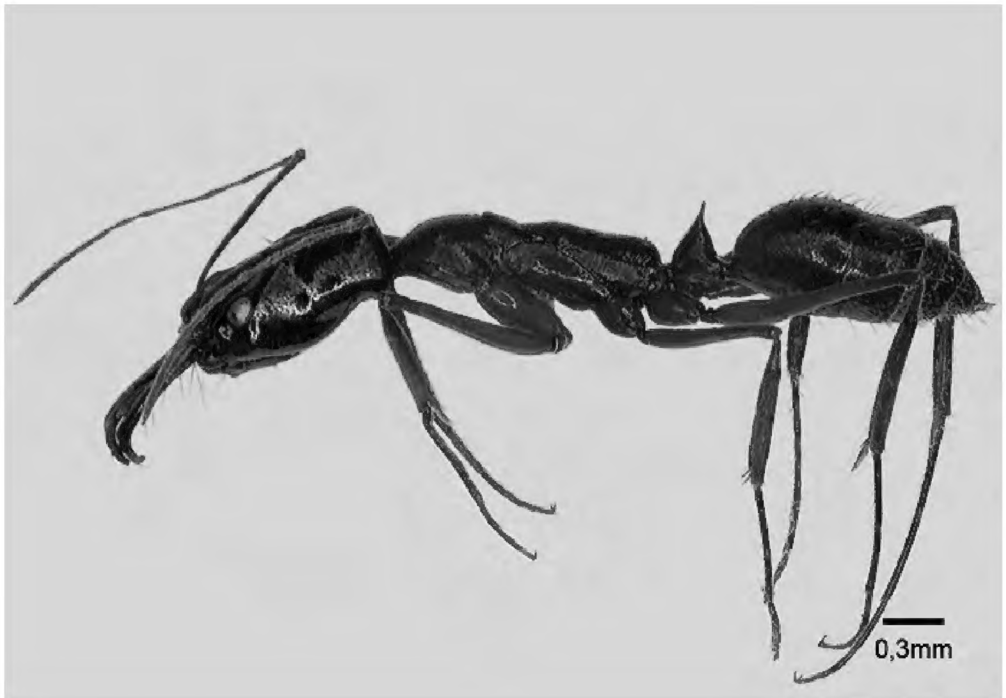

Figure A42. Subfamily Ponerinae: *Odontomachus chelifer*.

Figure A43. Subfamily Ponerinae: *Pachycondyla striata.*

Figure A44. Subfamily Pseudomyrmecinae: *Pseudomyrmex gracilis*.

Figure A45. Subfamily Pseudomyrmecinae: *Pseudomyrmex* sp. 3.